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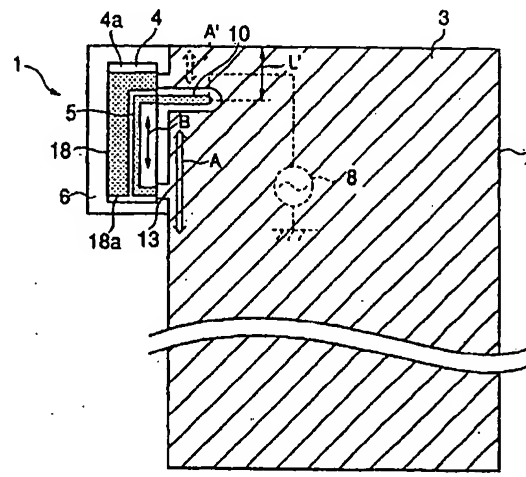
(54) Antenna and communication apparatus having the same

(57) An antenna-electrode structure (1) includes a feeding radiant-electrode (5) and a grounded portion (3) arranged such that an open-end of the feeding radiant-electrode (5) defines a capacitance to the grounded portion (3) therebetween, and a non-feeding radiant-electrode (18) arranged to electromagnetically couple the feeding radiant-electrode (5). The non-feeding radiant electrode (18) is arranged such that an open-end (18a) thereof defines a capacitance to the grounded portion (3) therebetween to produce a dual-frequency resonance state together with the feeding radiant-electrode (5). In response to a signal supplied from a signal-supply source (8), the feeding radiant-electrode (5) performs an antenna action and the non-feeding radiant-electrode (18) in turn performs an antenna action by signal transmission from the feeding radiant-electrode (5), such that by being excited from these actions, the grounded portion (3) also performs an antenna action. Because of the antenna action of the grounded portion (3), the sizes of the feeding radiant-electrode (5) and the non-feeding radiant electrode (18) are reduced.

FIG. 1A



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[0012] The grounded portion is provided on a circuit board of a communication apparatus, for example, and the position and size thereof can be varied such that the degree of design freedom is greatly increased. Therefore, even when the size of the feeding radiant-electrode and the non-feeding radiant-electrode is reduced (miniaturized), the transmission and reception of electric waves at a desired frequency bandwidth is performed with sufficient power by appropriately configuring the grounded portion. Moreover, the feeding radiant-electrode and the non-feeding radiant-electrode produce a dual-frequency resonance state, such that the frequency bandwidth is greatly increased as compared with a mono-resonance state where the non-feeding radiant-electrode is not provided.

[0013] Furthermore, because the feeding radiant-electrode and the non-feeding radiant-electrode are provided on the dielectric base-substance, the frequency of electric waves radiated from the feeding radiant-electrode and the non-feeding radiant-electrode is increased due to the wavelength reduction effect by the dielectric substance, enabling the size of the feeding radiant-electrode and the non-feeding radiant-electrode to be further reduced.

[0014] As described above, with the antenna-electrode structure according to preferred embodiments of the present invention, a simplified antenna-electrode structure having a greatly reduced size and an increased bandwidth is provided.

[0015] Although a direct-feeding type or a capacity-feeding type feeding radiant-electrode has outstanding characteristics, when a capacity-feeding type is provided, the feeding radiant-electrode can be provided separately from the feeding electrode, such that the feeding electrode is matched to the feeding radiant-electrode by the position of the feeding electrode, resulting in another advantage that a matching circuit is not required to be interposed between the feeding electrode and the signal-supply source.

[0016] When the feeding radiant-electrode and the non-feeding radiant-electrode are directly pattern-formed on the non-grounded portion of the substrate, manufacturing costs are reduced because the chip base-substance mentioned above is not required, and further, the manufacturing is simplified.

[0017] When the feeding radiant-electrode and the non-feeding radiant-electrode are arranged in the depositing direction via an insulating member interposing therebetween, the space between the feeding radiant-electrode and the non-feeding radiant-electrode can be more easily changed as compared with the case in which both the feeding radiant-electrode and the non-feeding radiant-electrode are provided on the top surface of the dielectric base-substance, for example, such that the amount of electromagnetic coupling between the feeding radiant-electrode and the non-feeding radiant-electrode is easily controlled. Thereby, the dual-frequency resonance state by the feeding radiant-electrode and the non-feeding radiant-electrode is further ensured.

[0018] A communication apparatus including the antenna-electrode structure according to preferred embodiments of the present invention is greatly reduced in size and has greatly increased frequency bandwidth in transmitting and receiving electric waves.

[0019] Other features, elements, characteristics and advantages of the present invention will become more apparent from the following detailed description of preferred embodiments thereof with reference to the attached drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0020]

Figs. 1A and 1B schematic representations showing an antenna-electrode structure according to a first preferred embodiment of the present invention.

Fig. 2 is a graph for showing an example of return-loss characteristics of the antenna-electrode structure according to the first preferred embodiment of the present invention.

Figs. 3A and 3B are schematic representations showing an example of electric-waves directivity of the antenna-electrode structure according to the first preferred embodiment of the present invention.

Figs. 4A and 4B are schematic representations showing an antenna-electrode structure according to a second preferred embodiment of the present invention.

Fig. 5 is a schematic representation showing an antenna-electrode structure according to a third preferred embodiment showing an extracted portion specific to the third preferred embodiment of the present invention.

Fig. 6 is a schematic representation showing an antenna-electrode structure according to a fourth preferred embodiment of the present invention.

Figs. 7A and 7B are schematic representations of other arrangement examples of a feeding radiant-electrode and a non-feeding radiant electrode.

Figs. 8A and 8B are schematic representations for showing an example of the experiment for obtaining the return loss and the antenna gain in the cases of the close arrangement and the separated arrangement of the feeding radiant-electrode and the non-feeding radiant electrode.

Figs. 9A and 9B are schematic views showing the cases of the close arrangement and the separated arrangement of the feeding radiant-electrode and the non-feeding radiant electrode.

Figs. 10A and 10B are graphs respectively showing the return loss and the antenna gain in the cases of the close arrangement and the separated arrangement of the feeding radiant-electrode and the non-feeding radiant electrode.

function, and a PDA (Personal Digital Assistance). In the communication apparatus according to the first preferred embodiment, any suitable components may be used other than the antenna-electrode structure 1, which will be described below, such that the description of the components of the communication apparatus other than the antenna-electrode structure 1 is omitted. Also, in the description of the antenna-electrode structure 1, like reference characters designate like functional portions common to those in the antenna-electrode structure 1 shown in Figs. 11A and 11B, and description thereof is omitted.

[0033] In addition to the configuration of the antenna-electrode structure 1 shown in Figs. 11A and 11B, the characteristic structure in the antenna-electrode structure 1 according to the first preferred embodiment is the arrangement of a non-feeding radiant electrode 18, as shown in Figs. 1A and 1B.

[0034] That is, in the first preferred embodiment, the feeding radiant-electrode 5, as shown in Fig. 1A, is provided on the top surface 4a of the chip base-substance 4 and has a substantially U-shape, and the open-end 5a of the feeding radiant-electrode 5, as shown in Fig. 1B, extends to a side edge 4d of the chip base-substance 4 so as to define the capacity-loaded electrode which provides a capacitance to the grounded portion 3 therebetween, as described above.

[0035] The non-feeding radiant-electrode 18 mentioned above, as shown in Fig. 1A, is provided on the top surface 4a of the chip base-substance 4 and has a substantially L-shape along the outside of the substantially U-shaped feeding radiant-electrode 5 via a spacing. One end of the non-feeding radiant-electrode 18 extends to the side edge 4d of the chip base-substance 4 so as to define a grounded end-portion electrically connected to the grounded portion 3.

[0036] The other end of the non-feeding radiant-electrode 18 is an open-end 18a. The open-end 18a of the non-feeding radiant-electrode 18 is arranged in the vicinity of the open-end 5a of the feeding radiant-electrode 5 so as to define a capacity-loaded electrode which provides a capacitance to the grounded portion 3 therebetween. The non-feeding radiant-electrode 18, together with the feeding radiant-electrode 5, is configured to produce return-loss characteristics shown in the solid line α of Fig. 2, i.e., a dual-frequency resonance state. In addition, to produce the dual-frequency resonance state by the feeding radiant-electrode 5 and the non-feeding radiant-electrode 18, various factors, such as an electric field coupling state and magnetic field coupling state of the radiant electrodes 5 and 18 are related. Considering such factors, according to the first preferred embodiment, to produce the dual-frequency resonance state and also to achieve the transmission and reception of electric waves in a desired frequency bandwidth, shapes and sizes (lengths) of the feeding radiant-electrode 5 and the non-feeding radiant-electrode 18, and the space between the feeding radiant-electrode 5 and the non-feeding radiant-electrode 18 are respectively adjusted. There are various design techniques for the feeding radiant-electrode 5 and the non-feeding radiant-electrode 18, and any one of them may be adopted therein such that the description thereof is omitted.

[0037] The antenna-electrode structure 1 according to the first preferred embodiment is configured as described above. In the antenna-electrode structure 1 according to the first preferred embodiment, when a signal is supplied to the feeding electrode 11 from the signal-supply source 8 via the feeding wiring-pattern 10, the signal is directly fed to the feeding radiant-electrode 5 from the feeding electrode 11. Also, due to this signal supply, the signal is supplied to the non-feeding radiant-electrode 18 from the feeding radiant-electrode 5 by electromagnetic coupling. Due to such signal supply, the feeding radiant-electrode 5 and the non-feeding radiant-electrode 18 respectively perform an antenna action so as to produce the dual-frequency resonance state.

[0038] Furthermore, according to the first preferred embodiment, since the respective open-ends 5a and 18a of the feeding radiant-electrode 5 and the non-feeding radiant-electrode 18 define capacitances to the grounded portion 3 therebetween, by being exited from each antenna action of the radiant electrodes 5 and 18, an electric current, as shown in A of Fig. 1A, (i.e., a current flowing in a direction connecting the feeding end-portion of the feeding radiant-electrode 5 to the open-end 5a, or a current flowing in a direction connecting the grounded end-portion of the radiant electrodes 5 and 18 to the open-end 18a) flows from the base end in the vicinity of the feeding end-portion of the feeding radiant-electrode 5. Thereby, the grounded portion 3 performs an antenna action corresponding to those of the radiant electrodes 5 and 18.

[0039] That is, according to the first preferred embodiment, the feeding radiant-electrode 5, the non-feeding radiant-electrode 18, and the grounded portion 3 perform the antenna action having return-loss characteristics in the dual-frequency resonance state, as shown in the solid line α of Fig. 2.

[0040] To allow the grounded portion 3 to perform a desired antenna action, the current carrying path length of the excited electric current A, which flows from the base end in the vicinity of the feeding end-portion of the feeding radiant-electrode 5 and is shown in Fig. 1A, is preferably at least greater than the physical length of the antenna. According to the first preferred embodiment, to provide the necessary current-carrying path length, an end region of the longer side of the substrate 2 is provided with the overhang 6 to mount the chip base-substance 4 thereon.

[0041] Also, according to the first preferred embodiment, the feeding end-portion of the feeding radiant-electrode 5 is provided at a position as close to a corner region of the grounded portion 3 as possible. The reason is that by being excited from each antenna action of the radiant-electrodes 5 and 18, the grounded portion 3 is

width BW2 is approximately 160 MHz when the capacity-loaded electrodes 5a and 18a of the respective radiant electrodes 5 and 18 are arranged to be spaced from each other whereas the bandwidth BW1 is approximately 200 MHz when the capacity-loaded electrodes 5a and 18a of the respective radiant electrodes 5 and 18 are arranged to be close to each other. At a frequency of 2450 MHz, the antenna gain when the capacity-loaded electrodes 5a and 18a are arranged to be close to each other is improved, by approximately 5 dB, than that when the capacity-loaded electrodes 5a and 18a are arranged to spaced from each other.

[0050] By arranging the capacity-loaded electrodes 5a and 18a to be close to each other, the bandwidth is increased and the antenna gain is improved.

[0051] In addition, the respective shapes of the feeding radiant-electrode 5 and the non-feeding radiant-electrode 18 are not limited to those shown in the first preferred embodiment, and various other shapes, such as a meander-shape, may be provided. However, when the respective radiant electrodes 5 and 18 are arranged in parallel with each other along the entire length thereof in the vicinity of the grounded portion 3, the current produced in the radiant electrodes 5 and 18 and the current A excited in the grounded portion 3 magnetically cancel each other because these currents have opposite phases. Thus, according to the first preferred embodiment, although the open-ends 5a and 18a of the respective radiant electrodes 5 and 18 must be arranged in the vicinity of the grounded portion 3 in order to define a capacitance to the grounded portion 3 therebetween to produce capacity-loaded electrodes, as described above, it is preferable that portions other than those be separated from the grounded portion 3 by as much distance as possible.

[0052] Also, according to the first preferred embodiment, the open-end 5a of the feeding radiant-electrode 5 is provided on the side edge 4d of the chip base-substance 4 while the open-end 18a of the non-feeding radiant-electrode 18 is provided on the top surface 4a of the chip base-substance 4; however, the positions of the respective open-ends 5a and 18a are not specifically limited. That is, to appropriately excite a current in the grounded portion 3, capacities between the respective open-ends 5a and 18a of the radiant electrodes 5 and 18 and the grounded portions 3 must be determined. The appropriate capacities are determined by the arrangement of the respective open-ends 5a and 18a of the radiant electrodes 5 and 18, such that the arrangement is not limited to that of the first preferred embodiment.

[0053] Moreover, according to the first preferred embodiment, the grounded electrode 12 is arranged as shown in Fig. 1B. However, the grounded electrode 12 may be omitted depending on the required capacitance between the open-end 5a of the feeding radiant-electrode 5 and the grounded portion 3.

[0054] Next, a second preferred embodiment of the present invention will be described below. Fig. 4A is a top plan view schematically showing an antenna-electrode structure 1 according to the second preferred embodiment of the present invention. Fig. 4B schematically shows the chip base-substance 4 in a developed state, which defines the antenna-electrode structure 1. In addition, in the description of the second preferred embodiment, like reference characters designate like elements common to those in the antenna-electrode structure 1 according to the first preferred embodiment, and the description thereof is omitted.

[0055] The antenna-electrode structure 1 according to the second preferred embodiment is similar to the antenna-electrode structure 1 according to the first preferred embodiment. However, the feeding radiant-electrode 5 according to the first preferred embodiment is a direct feeding type, whereas in the second preferred embodiment, it is a capacity feeding type.

[0056] That is, according to the second preferred embodiment, the feeding electrode 11 electrically connected to the signal-supply source 8 is provided along the feeding radiant-electrode 5 via a spacing therebetween. One end of the feeding radiant-electrode 5, as in the first preferred embodiment, is the open-end 5a, which is the capacity-loaded electrode, and the other end is a grounded end, which is electrically connected to the grounded portion 3. The impedance of the feeding radiant-electrode 5 increases from the grounded end thereof toward the open-end. When the impedance of the feeding electrode 11 is about 50 Ω, for example, the feeding electrode 11 is provided at a position opposing a portion of the feeding radiant-electrode 5 having an impedance of about 50 Ω. The feeding radiant-electrode 5 and the feeding electrode 11 are thereby matched to each other.

[0057] In such a manner, the feeding electrode 11 is provided at a position of the feeding radiant-electrode 5 via a spacing therebetween where the feeding electrode 11 is matched to the feeding radiant-electrode 5.

[0058] The second preferred embodiment, as in the first preferred embodiment, transmits and receives electric waves having sufficient power and has a greatly increased bandwidth even when the size of the radiant electrodes 5 and 18 is reduced. Moreover, since the feeding radiant-electrode 5 is a capacity-feeding type in the second preferred embodiment, the feeding radiant-electrode 5 is matched to the signal-supply source 8 without a matching circuit, resulting in the elimination of the matching circuit.

[0059] Next, a third preferred embodiment will be described below. Fig. 5 is a drawing of an antenna-electrode structure according to the third preferred embodiment. According to the third preferred embodiment, as shown in Fig. 5, the feeding radiant-electrode 5 and the non-feeding radiant-electrode 18 are arranged with an insulating member (a dielectric substance, for example) 20 interposed therebetween in a depositing direction. The other features are the same as those in the first and

of the feeding radiant-electrode 5 and the non-feeding radiant-electrode 18.

[0072] In the preferred embodiments described above, both of the feeding radiant-electrode 5 and the non-feeding radiant-electrode 18 are provided. However, one of the feeding radiant-electrode 5 and the non-feeding radiant-electrode 18 or a plurality of both electrodes 5 and 18 may be formed, such that each number of electrodes 5 and 18 is not limited. In this case, bandwidth is further increased.

[0073] Furthermore, the radiant electrodes 5 and 18 are appropriately arranged in consideration of the path length of the excited current A and the electric-wave directivity of the grounded portion 3, and the arrangement thereof is not limited to the arrangements shown in the preferred embodiments described above.

[0074] While preferred embodiments of the invention have been described above, it is to be understood that variations and modifications will be apparent to those skilled in the art without departing the scope and spirit of the invention. The scope of the present invention, therefore, is to be determined solely by the following claims.

Claims

1. An antenna-electrode structure (1) comprising:

   a substrate (2);
   a grounded portion (3) provided on the substrate (2);
   a non-grounded portion (6)on which an antenna is mounted;
   a feeding radiant-electrode (5) into which a signal is supplied from a signal supply source (8);
   a non-feeding radiant-electrode (18) arranged adjacent to the feeding radiant electrode (5) in a direction separated from the grounded portion (3) via a space therebetween for producing a dual-frequency resonance state by electromagnetic coupling with the feeding radiant-electrode (5); and
   a dielectric base substance (4) surface-mounted on the substrate (2) and having the feeding radiant-electrode (5) mounted thereon; wherein
   one end (5a) of the feeding radiant-electrode (5) is open so as to define a capacitance to the grounded portion (3) therebetween; and
   wherein the non-feeding radiant-electrode (18) is provided on the dielectric base substance (4) along the feeding radiant-electrode (5) and one end of the non-feeding radiant-electrode (18) is connected to the grounded portion while the other end (18a) is open, the open-end (18a) of the non-feeding radiant electrode (18) defining a capacity-loaded electrode forming a capacitance to the grounded portion (3) therebetween at a position close to a capacity portion located between the open-end (5a) of the feeding radiant-electrode (5) and the grounded portion (3).

2. An antenna-electrode structure (1) comprising:

   a substrate (2);
   a grounded portion (3) provided on the substrate (2);
   a non-grounded portion (6) on which an antenna is mounted;
   a feeding radiant-electrode (5) into which a signal is supplied from a signal supply source (8) and having a substantially U-shape;
   a non-feeding radiant-electrode (18) arranged adjacent to the feeding radiant electrode (5) in a direction separated from the grounded portion via a space therebetween for producing a dual-frequency resonance state by electromagnetic coupling with the feeding radiant-electrode (5); wherein
   one end of the feeding radiant-electrode (5) is open so as to define a capacitance to the grounded portion (3) therebetween; and
   wherein the non-feeding radiant-electrode (18) is provided on the non-grounded portion (6) along the feeding radiant-electrode (6) and one end of the non-feeding radiant-electrode (18) is connected to the grounded portion (3)while the other end (18a) is open, the open-end (18a) of the non-feeding radiant electrode (18) defining a capacity-loaded electrode forming a capacitance to the grounded portion (3) therebetween at a position close to a capacity portion located between the open-end (5a) of the feeding radiant-electrode (5) and the grounded portion.

3. An antenna-electrode structure (1) according to Claim 2, wherein the feeding radiant-electrode (5) and the non-feeding radiant-electrode (18) are directly located and pattern-formed on the non-grounded (6) portion on the substrate (2).

4. An antenna-electrode structure (1) according to any of claims 1 to 3, further comprising an insulating member, wherein the feeding radiant-electrode (5) and the non-feeding radiant-electrode (18) are arranged with the insulating member provided therebetween.

5. An antenna-electrode structure (1) according to any of claims 1 to 4, further comprising a feeding electrode electrically connected to the signal supply source (8), wherein the feeding radiant-electrode (5) communicates and connects to the feeding electrode (11) so as to define a directly-feeding-type feeding radiant-electrode (5) in which a signal is di-

FIG. 1A

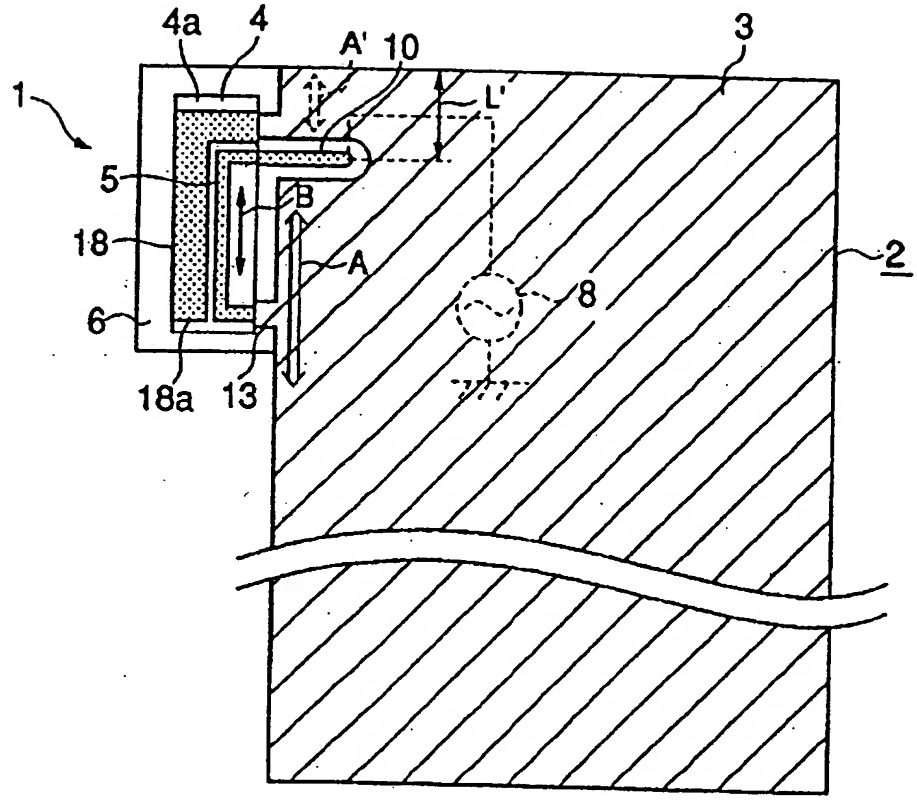
4a
4
A'
10
3
1
5
B
18
A
L'
2
8
6
18a
13

FIG. 1B

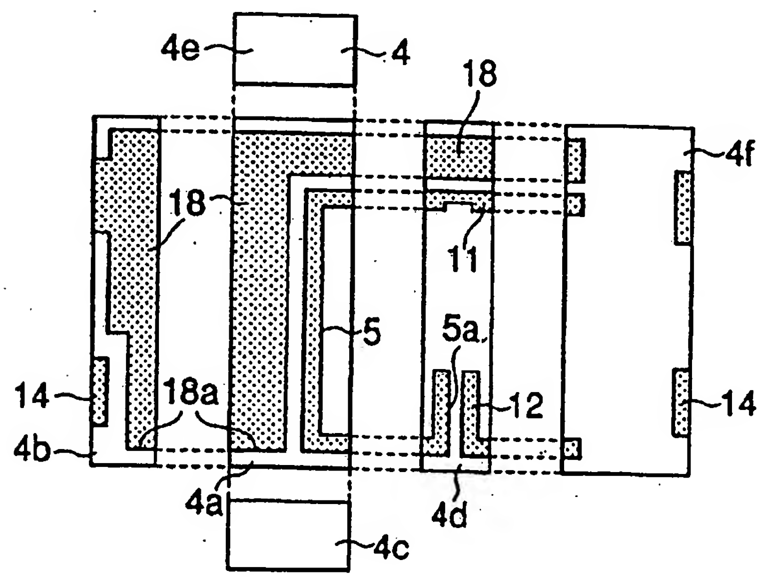
4e
4
18
4f
18
11
5
5a
14
18a
12
14
4b
4a
4d
4c

FIG. 3A

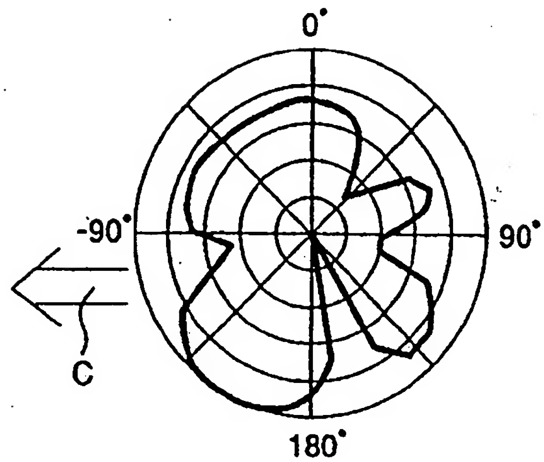

FIG. 3B

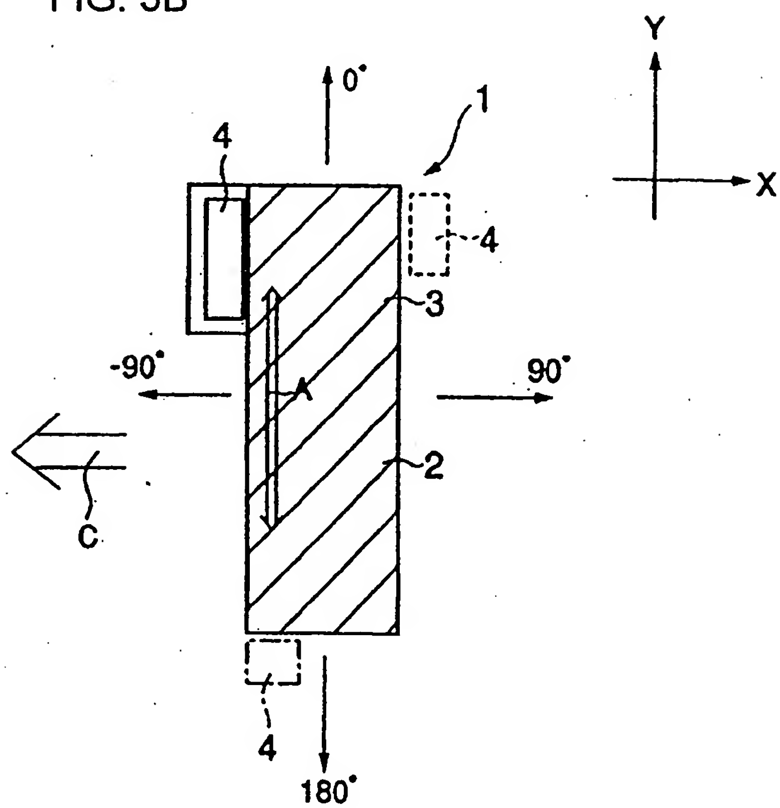

FIG. 5

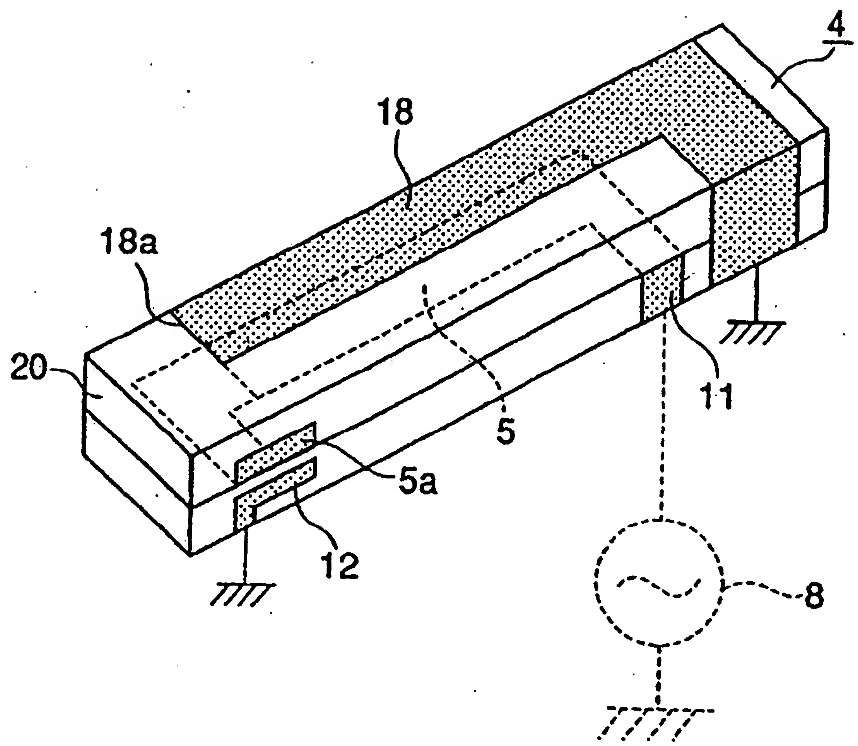

FIG. 7A

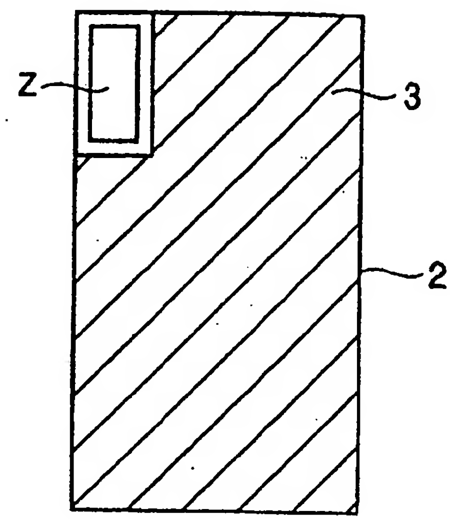

FIG. 7B

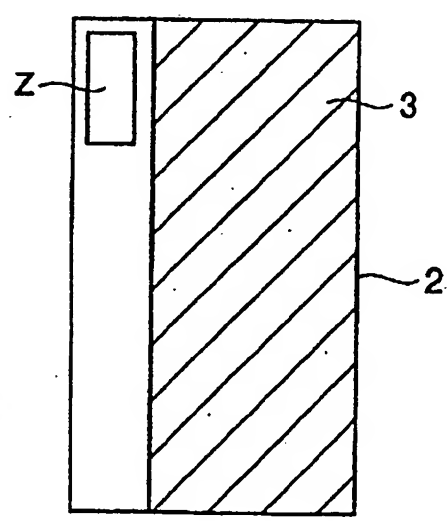

FIG. 9A

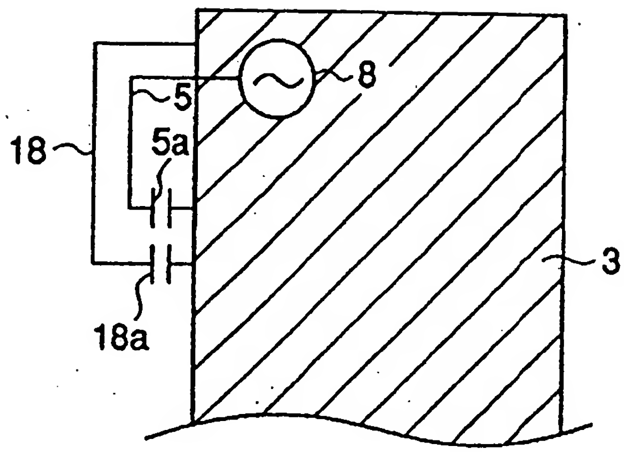

FIG. 9B

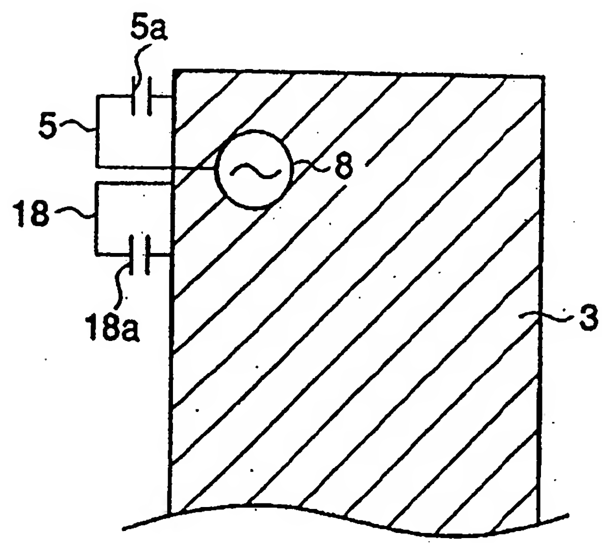

FIG. 11A

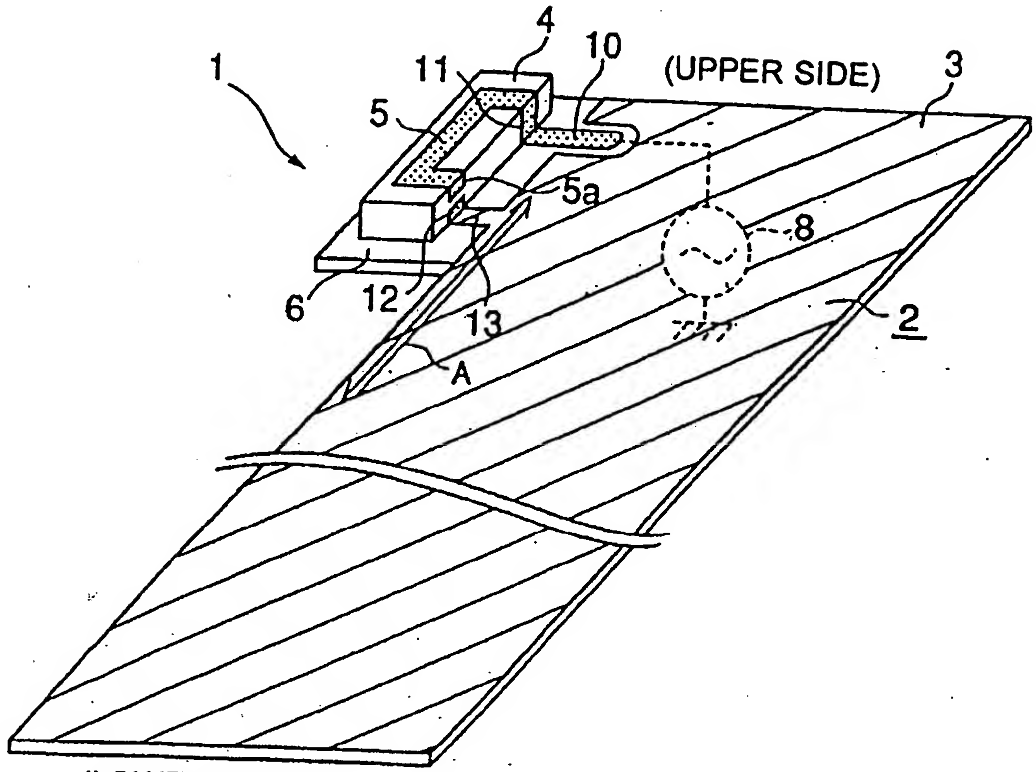

FIG. 11B